Mathematical Study of CO₂ Dispersion in Carbonated Water Injection Enhanced Oil Recovery Using Non-Equilibrium 2D Simulator

Authors : Ahmed Abdulrahman, Jalal Foroozesh

Abstract : CO₂ based enhanced oil recovery (EOR) techniques have gained massive attention from major oil firms since they resolve the industry's two main concerns of CO₂ contribution to the greenhouse effect and the declined oil production. Carbonated water injection (CWI) is a promising EOR technique that promotes safe and economic CO₂ storage; moreover, it mitigates the pitfalls of CO_2 injection, which include low sweep efficiency, early CO_2 breakthrough, and the risk of CO_2 leakage in fractured formations. One of the main challenges that hinder the wide adoption of this EOR technique is the complexity of accurate modeling of the kinetics of CO₂ mass transfer. The mechanisms of CO₂ mass transfer during CWI include the slow and gradual cross-phase CO₂ diffusion from carbonated water (CW) to the oil phase and the CO₂ dispersion (within phase diffusion and mechanical mixing), which affects the oil physical properties and the spatial spreading of CO₂ inside the reservoir. A 2D non-equilibrium compositional simulator has been developed using a fully implicit finite difference approximation. The material balance term (k) was added to the governing equation to account for the slow cross-phase diffusion of CO₂ from CW to the oil within the gird cell. Also, longitudinal and transverse dispersion coefficients have been added to account for CO₂ spatial distribution inside the oil phase. The CO₂-oil diffusion coefficient was calculated using the Sigmund correlation, while a scaledependent dispersivity was used to calculate CO₂ mechanical mixing. It was found that the CO₂-oil diffusion mechanism has a minor impact on oil recovery, but it tends to increase the amount of CO₂ stored inside the formation and slightly alters the residual oil properties. On the other hand, the mechanical mixing mechanism has a huge impact on CO₂ spatial spreading (accurate prediction of CO₂ production) and the noticeable change in oil physical properties tends to increase the recovery factor. A sensitivity analysis has been done to investigate the effect of formation heterogeneity (porosity, permeability) and injection rate, it was found that the formation heterogeneity tends to increase CO₂ dispersion coefficients, and a low injection rate should be implemented during CWI.

Keywords : CO₂ mass transfer, carbonated water injection, CO₂ dispersion, CO₂ diffusion, cross phase CO₂ diffusion, within phase CO₂ diffusion, CO₂ mechanical mixing, non-equilibrium simulation

Conference Title : ICOOGT 2020 : International Conference on Offshore Oil and Gas Technology

Conference Location : Kuala Lumpur, Malaysia

Conference Dates : December 17-18, 2020

1